Contribution ID: **250** Type: **Presentazione orale**

On the applicability of nonlinear inverse FEM for shape sensing of plates under blast loading

Friday 4 September 2026 09:00 (15 minutes)

The inverse Finite Element Method (iFEM) is a robust and efficient technique for reconstructing full-field displacements from sparse strain measurements, requiring only structural geometry, boundary conditions, and sensor data—without relying on material properties or external load information. This load-independence makes iFEM attractive for Structural Health Monitoring (SHM) and Digital Twin (DT) frameworks, yet its applicability to highly transient, large-deformation events remain less explored. In this work, we assess the use of a nonlinear iFEM formulation for real-time shape sensing of plates subjected to blast loading, where geometric nonlinearity, membrane–bending coupling, and steep spatial gradients can undermine linear reconstruction. The proposed approach embeds geometrical nonlinearity within the inverse least-squares finite element framework to improve reconstruction fidelity during impulsive response and post-peak oscillations. A systematic numerical campaign is performed on representative blast-driven plate configurations, varying boundary conditions, sensor layouts, and measurement noise, and benchmarking reconstructions against high-fidelity finite element simulations. Results indicate that the nonlinear iFEM markedly enhances displacement field accuracy compared with linear iFEM, particularly when large deflections dominate and when sensor networks are sparse. The study further quantifies sensitivity to instrumentation strategies, highlighting conditions under which nonlinear iFEM provides stable, near real-time reconstructions suitable for blast-resilient structures and DT-enabled decision support.

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Session Classification: Xtrema

Track Classification: High Strain Rates